DATA ANALYTICS IN FIELD OF RENEWAL ENERGY

A Synopsis of the proposed thesis to be submitted for the degree of

Doctor of Philosophy

by

Laxmi Kant Sagar

Under the supervision of

Supervisor
Prof. D. Bhagwan Das
Electrical Department
DEI, Agra

Co-Supervisor
Prof. P. R. Bijwe
Electrical Department
IIT, Delhi

DEPARTMENT OF PHYSICS AND COMPUTER SCIENCE
DAYALBAGH EDUCATIONAL INSTITUTE
(DEEMED UNIVERSITY)
DAYALBAGH, AGRA (INDIA)
OCTOBER, 2017

LIST OF CONTENTS

List of content i

List of figures ii

1 Introduction **1**

2 Literature Survey **3**

2.1 Introduction of Micro Grid 4

2.2 Advancement in solar forecasting and generation 5

2.3 Models to Analyze Energy, Environmental and Sustainability 8

2.4 Smart Energy Management 10

3 Scope of the work **11**

References **15**

LIST OF FIGURES

1. Power grid with integrated renewable sources and its usage of machine learning techniques. 2

2. Whole process decision support of big data for smart grid management 11

1. Introduction

With the steady increase in population, electrical energy has only seen increasing demand over the centuries and still multi-folding. While India continues to add generation capacity, the gap between demand and supply remains wide. As per CEA report In India, during the fiscal year 2016-17, the energy availability was 1,135.334 billion KWh with a short fall of requirement by 7.595 billion KWh (-0.7%) against the 1.1% surplus anticipated. The peak load met was 156,934 MW with a short fall of requirement by 2,608 MW (-1.6%) against the 2.6% surplus anticipated.

Renewable energy e.g. solar, wind etc. can be solution to meet the increasing demand, it has become increasingly popular in recent years due to environmental concerns resulting from fossil fuel consumption in conventional power plants. The conventional power generators are mainly gas turbines and steam turbines. Till now, it is not possible to completely replace the conventional sources with renewable sources. Although, a mix of these is a viable solution and current research is in process in this area this generation mix is changing with the rapid growth in the number of renewable power plants such as solar power, wind power, hydroelectricity/micro hydro, biomass and biofuels for transportation

With the government plan of installing 100 GW of Solar Power by 2022, the need to identify the methodology to maximize the solar generation, optimize the operations and enable integration to the grid becomes extremely relevant, as renewable energy possess many advantages over non-renewable energy resources but reliability and performance is still major concern. Big Data analytics can play a crucial role in achieving this objective, as the sensors installed in solar panels generates huge amount of data, which can be analyzed in real time to give the desired operational performance parameters. Analytical models enable solar energy to gain deeper insights into the variable nature of wind and solar, and more accurately forecast the amount of energy that can be redirected into the power grid or stored.

Data analytics mainly falls into three categories viz. power forecasting, condition based monitoring or predictive maintenance, overall solar system performance & reliability analysis.

With the development of big data technologies in the field of data storage & retrieval, real time processing, analytical modelling and visualization, there is an immense scope to provide value to the developers, generators, utilities & end users.

Data Analytics i.e. Artificial intelligence and Machine learning can be used to overcome the problem of reliability and performance up to great extend and can increase output of renewable energy to a great extent percentage without much building.

Data analytics is the process of examining data sets in order to draw conclusions about the information they contain, increasingly with the aid of specialized systems and software. Data analytics technologies and techniques are widely used to make more-informed business decisions and by scientists and researchers to verify or disprove scientific models, theories and hypotheses.

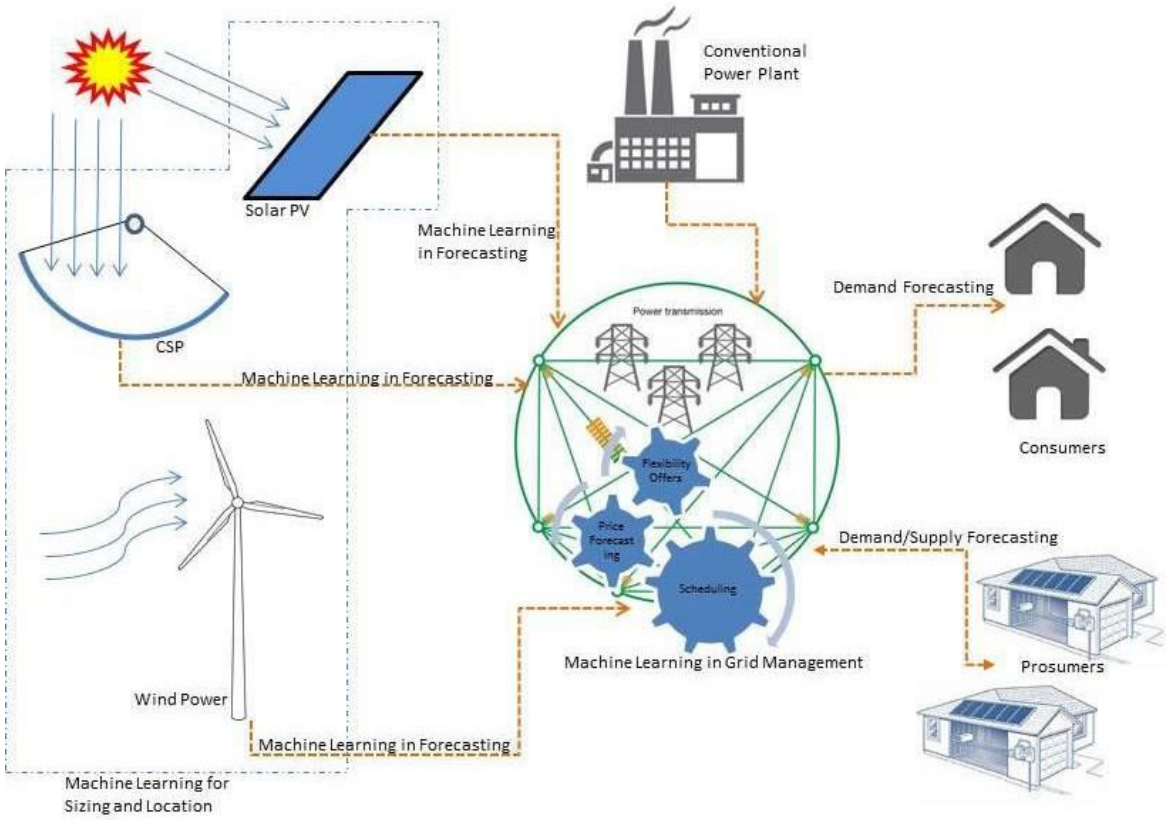

Fig. 1. Power grid with integrated renewable sources and its usage of machine learning techniques.

Big data technology along with machine learning can be employed as it can give strong forecasting performance, to conduct fast real time simulation for the electricity system and improve intelligence level of analytical decision making. Variables such as temperature, atmospheric pressure, humidity, rainfall, wind direction, wind force, radiation etc. are taken into full account to arrive at more accurate forecasts. Electric power system modelling, incorporating big data analytics and numerical whether forecasts can improve the smoothness of wind and solar voltaic power supply. With data technology, power dispatches can work out scheduling arrangements ahead of time and contribute to the more consumption of more renewable energy.

Big Data, with their potential to ascertain valued insights for enhanced decision-making process, have recently attracted substantial interest from both academics and practitioners. Big Data Analytics is increasingly becoming a trending practice that many organizations are adopting with the purpose of constructing valuable information from Big Data.

Big Data Analytics can be used in the following fields of solar system which include

- Smart Grid
- Battery
- Smart Monitoring
- Future Load Demand prediction
- Identifying harmful potential conditions
- Line Faults etc.

2. LITERATURE SURVEY

Achieving solutions to energy problems that we face today requires long-term potential actions for sustainable development. In this regard, renewable energy resources appear to be the one of the most efficient and effective solutions. Potential solutions to current environmental problems are identified along with renewable energy technologies. A large number of national and international studies have been conducted to study the opportunities of Data Analytics for improving energy efficiency of renewable energy mainly PV system. These studies show that, it is quite possible to limit the increase in energy use without having negative effects. Lot of work has been done in:

- Integration of Micro Grid
- Advancement in solar power forecasting and generation
- Models to Analyze Energy, Environmental and Sustainability
- Environmental performance evaluation
- Smart energy management

The important papers and their contributions belonging to each framework are discussed below one by one.

2.1 Integration of Micro Grid

Micro Grid is one of the major component of PV system, by optimizing it output form PV system can be increased to great extent. The increasing number of renewable energy sources and distributed generators requires new strategies for the operation and management of the electricity grid in order to maintain or even to improve the power-supply reliability and quality (Juan et al., 2006)

Design of micro Grid Model (Deepak et al., 2011). The system consists of the power plant using renewable energy sources, such as photovoltaic (PV), micro hydro (MHP), wind, biomass, and others, employing battery storage or conventional diesel generator, that can be connected to the grid system or standalone configuration are identified as the micro-grid. The use of the micro-grid in the off-grid area, a combination of power plants using renewable energy sources is also complemented by the diesel generator. Meanwhile, in the on-grid area, the combination would be complemented by the electricity supply of the grid system. This paper analyzes the possibility to develop the simple micro-grid model optimizing the utilization of local renewable energy for on- grid area

Use of artificial intelligence optimization of micro-grid system is done, which greatly improves the output of solar system by optimizing the battery scheduling in dynamic environment of load and available solar power (Leo et al., 2014). This paper makes use of reinforcement learning algorithm, namely Q Learning, to optimize the battery scheduling in dynamic environment of load and available solar power. Multiple agents sense the states of the environment components and make collective decisions about how to respond to randomness in load, intermittent solar power using a Multi-Agent Reinforcement Learning algorithm, called Coordinated Q Learning (CQL). The goals of each agent are to increase the utility of the battery and solar power in order to achieve the long-term objective of reducing the power consumption from grid.

Reference. (Phiri et al., 2016) Proposes a multi-objective energy management model in order to optimize the short-term operation of a grid connected hybrid system supplying an industrial load while participating to the Time of Use Demand Side Management program. The main purpose of the developed model is to minimize the operation cost of a proposed grid-connected hybrid energy system consisting of a photovoltaic unit, a wind unit and a battery storage system while optimizing the system's power flow considering the different component's operational constraints. The

simulations have been performed using “linear programming” implemented in MATLAB. The simulation results demonstrate that the developed model can assist the hybrid system in reducing the operation cost and allow consumers to generate substantial income by selling power to the grid.

(Sheeraz et al., 2018) proposes an effective technique for integration of solar/wind system to microgrid. A control model for integration of hybrid energy sources to the microgrid and the effectiveness of the control algorithm for DC/DC converter under variation of different load demands are presented. A nearly constant dc voltage at the output of hybrid energy system is preferred for high efficiency So, there is a necessity for developing control techniques for a grid integration hybrid system including a method for output voltage control that stabilizes the voltage and dc-link capacitance.

2.2 Advancement in solar power forecasting and generation

Solar power is rapidly becoming a generation technology of significance. Unpredictability and variability of wind power generation is one of the fundamental difficulties faced by power system operators. Good forecasting tools are urgent needed under the relevant issues associated with the integration of solar energy into the power system.

An evolutionary optimization algorithm is used in (Francesco et al., 2011) as a tool for training an Artificial Neural Network used for production forecasting of solar energy PV plants. This optimized procedure essentially represent a bio-inspired heuristic search technique which is used to solve complex forecasting problems modelled on the concepts of biological neurons. Some simulation results are reported to highlight advantages and drawbacks of the proposed method in order to suitably apply this algorithm to a neuro-fuzzy system application in solar energy production. The weather forecast data related to the PV plants are supplied by the airport service close to the production site and relative data are pre-processed using Fuzzy Logic techniques.

Forecasting hourly global horizontal solar radiation based on the combination of unsupervised k-means clustering algorithm and artificial neural networks (ANN) (Khalil et al., 2013). K-Means algorithm focused on extracting useful information from the data with the aim of modelling the time series behavior and find patterns of the input space by clustering the data. On the other hand, nonlinear autoregressive (NAR) neural networks are powerful computational models for modelling and forecasting nonlinear time series. Taking the advantage of both methods, a new method was

proposed combining *k*-means algorithm and NAR network to provide better forecasting results.

Various forecasting techniques are computed and compared (Hugo et al., 2012). The methods studied in this work are: Persistent model, Auto-Regressive Integrated Moving Average (ARIMA), k-Nearest-Neighbors (kNNs), Artificial Neural Networks (ANNs), and ANNs optimized by Genetic Algorithms (GAs/ANN). The accuracy of the models is determined by computing error statistics such as mean absolute error (MAE), mean bias error (MBE), and the coefficient of correlation (R2) for the differences between the forecasted values and the measured values for the specific period. The results show ANN-based forecasting models perform better than the other forecasting techniques. Substantial improvements can be achieved with a GA optimization of the ANN parameters.

Various machine learning techniques used in solar photovoltaic (PV). Thermo siphon solar heater is a way of using renewable energy to get hot water for domestic usage. (Kalogirou et al., 1999) conducted performance prediction for these devices using ANN. The performance was measured in terms of the useful energy extracted and of the stored water temperature rise. The ANN was trained using the performance data for four types of systems, all employing the same collector panel under varying weather conditions. The output of ANN is the useful energy extracted from the system and the water temperature rise. Seven input units, 24 hidden neurons and 2 neurons as output comprises the network model with Sigmoid as the transfer function.

A prediction model for solar power generation based on weather parameters was used different machine learning techniques (Sharma et al., 2014). Multiple regression techniques including least-square SVM using multiple kernel functions were used in the comparison with other models. Experimental results showed that the SVM model outperformed the others with up to 27% more accuracy. Linear least-square regression model was also used for prediction with 7 weather parameters and results indicate 165W/m2 and 130W/m2 RMSE for validation and prediction sets respectively. For the SVM-based model they tired linear, polynomial and RBF kernels, and chose the RBF kernel for the final SVM model (as the first two did not perform well). Further improvement to the model was made by using principal component analysis (PCA), thus by selecting the first 4 features from the ranked output features from PCA. A hybrid intelligent predictor for 6 hour ahead solar power prediction was proposed (Hossain et al., 2012). The system used an ensemble method with 10 widely-used regression models namely linear regression (LR), radial basis function (RBF), SVM, MLP, pace regression (PR), simple linear regression (SLR), least median square (LMS), additive regression (AR), locally weighted learning (LWL) and IBk (an

implementation of kNN). Their results showed that, with respect to MAE and MAPE, the top most accurately performing regression models are LMS, MLP, and SVM. (Diagne et al., 2013) recently provided a survey of solar energy forecasting methods covering various physical and statistical/machine learning techniques.

Earlier stochastic learning and the general use of artificial intelligence methods in solar forecasting (Pourmousavi et al., 2011). More recently, new forecasting algorithms that go beyond the use of simple pattern recognition algorithms have gained attention. These more comprehensive stochastic learning techniques attempt to remove the opinion of the modeller in the optimization of the topology, initial weights and coefficients of the neural networks through a Master Optimization Process (MOP) that is usually evolutionary in nature. The MOP "evolves" the topology of the various artificial neural networks (ANNs) (number of neurons, layers, initial weights, size of the training set, etc.) by scanning the whole solution space of the training set with an evolutionary optimization scheme such as a Genetic Algorithm (GA). This multi-objective, multi-layer optimization determines the best topologies and the best sections of the training set for each microclimate under study and may or may not include dynamic input selection for exogenous variables through Gamma tests (Marquez and Coimbra, 2011). Because of their robust and versatile nature, these hybrid schemes outperform persistence, conventional regression (ARMA, ARIMA, f-ARIMA, etc.) and pattern recognition methods (kNN, ANN, etc.), producing higher-fidelity forecasts with or without exogenous variables at various horizons (Pedro and Coimbra, 2012; and Marquez et al., 2012).

(Weicong et al., 2017) proposes a long short-term memory (LSTM) recurrent neural network (RNN) based framework, which is the latest and one of the most popular techniques of deep learning.

Simple forecasting database infrastructure using the open-source database management system MySQL has been implemented by (Hugo et al., 2018). This proposal aims at advancing the myriad of solar and wind forecast models present in the literature into a production stage. The paper gives all relevant details necessary to implement a MySQL infra-structure that collects the raw data, filters unrealistic values, classifies the data, and produces forecasts automatically and without the assistance of any other computational tools. The performance of this methodology is demonstrated by creating intra-hour power output forecasts for a 1 MW photovoltaic installation and a 10 MW wind power plant. Several machine learning forecast models are implemented (persistence, auto-regressive and nearest neighbors) and tested. Both point forecasts and prediction intervals are generated with this methodology. Quantitative and qualitative analyses of solar and wind power forecasts were performed for an extended testing period (4 years and 6 years, respectively).

Weighted Gaussian process regression approach has been discussed by (Hanmin et al., 2018) for outlier detection. Photovoltaic (PV) power is volatile in nature and raises the level of uncertainty in power systems. PV power forecasting is an important measure to solve this problem. It helps to improve the reliability and reduces the generation cost. Advances in computer technology and sensors make the numeric modeling methods a hotspot in the field of PV power forecasting. However, data modeling methods strongly rely on the accuracy of measurement data. In this study, an innovative method employing the weighted Gaussian process regression approach is proposed, such that data samples with higher outlier potential have a low weight. A density-based local outlier detection approach is introduced to compensate the deterioration of Euclidean distance for high-dimensional data. A novel concept of the degree of nonlinear correlation is incorporated to compute the contribution of every individual data attribute.

2.3 Models to Analyze Energy, Environmental and Sustainability

Multi-Criteria Decision-Making techniques are gaining popularity in sustainable energy management. The techniques provide solutions to the problems involving conflicting and multiple objectives. Several methods based on weighted averages, priority setting, outranking, fuzzy principles and their combinations are employed for energy planning decisions.

During the 1970s, energy planning efforts were directed primarily towards energy models aimed at exploring the energy–economy relationships established in the energy sector. The main objectives followed were to accurately estimate future energy demand. A single criteria approach aimed at identifying the most efficient supply options at a low cost was popular (Pourmousavi et al., 2012). In the 1980s, growing environmental awareness has slightly modified the above decision framework (Nehrir et al., 2011). The need to incorporate environmental and social considerations in energy planning resulted in the increasing use of multi criteria approaches.

Multi-objective linear programming is another planning methodology used for illustrating the trade-off between environmental and economic parameters and for assisting in the selection of a compromise solution (Aouni et al., 2013). It was popular in energy planning with conventional fuels in the 1970s. However, after the oil shock of 1973, a thought was given for energy conservation and energy substitution. Renewable energy sources are being promoted for a wide variety of applications worldwide. They are free from any form of pollution and are capable of substituting

for conventional fuels in most of the applications. However, the contribution of these sources is very low, despite considerable technological development and their increasing competitiveness with respect to conventional fuels. This compels the planners and decision makers to identify the barriers for penetration and suggest interventions to overcome them. It is therefore felt that, along with the necessary policy measures, the wide exploitation of sustainable energy should be based on a completely different conception of energy planning procedure. The role of different actors in decision making thus becomes important. Methods of group decision are therefore of primary interest for the implementation of decision sciences in real-life problems.

Multi-criteria decision making (MCDM) methods deal with the process of making decisions in the presence of multiple objectives. A decision-maker is required to choose among quantifiable or non-quantifiable and multiple criteria. The objectives are usually conflicting and therefore, the solution is highly dependent on the preferences of the decision-maker and must be a compromise. In most of the cases, different groups of decision-makers are involved in the process. Each group brings along different criteria and points of view, which must be resolved within a framework of understanding and mutual compromise. Applications of MCDM include areas such as integrated manufacturing systems (Aouni et al., 2014), evaluations of technology investment (Arnette et al., 2014), water and agriculture management in addition to energy planning (Momoh et al., 2009).

(Kiker et al., 2005) present recommendations for applying multi-criteria decision analysis techniques in environmental projects. Recent contributions in this area confirm the relevance of multi-criteria approach. Han et al. (2012) propose a multi-objective optimization model to determine available technologies to produce electricity and treat CO2 for maximizing the expected profits and minimizing the financial risk of handling uncertain environments.

Arnette and Zobel (2012) discuss a multi-objective linear programming model to be used to determine the optimal mix of renewable energy sources and existing fossil fuel facilities balancing the corresponding GHG emissions. The importance of fuzzy techniques to deal with multi criteria environmental decision making is shown. For instance, Agrawal and Singh (2001) analyze a fuzzy multi-objective energy allocation problem for cooking use in households. Borges and Antunes (2003) develop a fuzzy multiple objective decision support model to study the relationships between the economy and the energy sector on a national level. A fuzzy linear programming model is formulated by Sadeghi and Hosseini (2006) for the optimization of supply energy system. (Kazemi et al. 2011) allocate optimally, to each end-use, a certain amount of energy to be supplied by a given resource with an emphasis on GHG reduction using neural networks and fuzzy linear regression methods. Among all different multi-criteria decision-making techniques, a crucial role has been

played by goal programming and its variants. Simple forecasting database infrastructure has been implemented using the open-source database management system MySQL by (Hugo et al, 2018). This proposal aims at advancing the myriad of solar and wind forecast models present in the literature into a production stage. The paper gives all relevant details necessary to implement a MySQL infra-structure that collects the raw data, filters unrealistic values, classifies the data, and produces forecasts automatically and without the assistance of any other computational tools. The performance of this methodology is demonstrated by creating intra-hour power output forecasts for a 1 MW photovoltaic installation and a 10 MW wind power plant. Several machine learning forecast models such as persistence, auto-regressive and nearest neighbors are implemented and tested. Both point forecasts and prediction intervals are generated with this methodology. Quantitative and qualitative analyses of solar and wind power forecasts were performed for an extended testing period (4 years and 6 years, respectively).

2.3 Smart Energy Management

Currently, the energy sector is facing various challenges (Amin et al., 2008), such as challenges in operational efficiency and cost control (Altın et al., 2009), system stability and reliability (Zho et al., 2014), renewable energy management (Aalami et al., 2010), energy efficiency and environmental issues, as well as consumer engagement and service improvement to better deal with these challenges, energy big data analytics provide new opportunities by achieving smart energy management.

In smart grid, large amounts of and various types of data, such as device status data, electricity consumption data, and user interaction data, are being collected. Then, many data analysis techniques, including optimization (Samadi et al., 2010; Zhou et al., 2014; Bhattacharya et al., 2010), forecasting (Chen et al., 2010; Hong et al., 2011; Fan et al., 2012), classification and clustering (Grandjean et al., 2012; Zhou et al., 2013; Ferreira et al., 2013; Zhou et al., 2014), can be applied on the large amounts of smart grid big data. Thereby, power generation and operation can be optimized in real time, electricity demand can be predicted accurately, electricity consumption patterns can be discovered precisely, and dynamic pricing mechanisms can be developed effectively. Based on big data analytics, smart grid can detect and restore from failures rapidly, response electricity demand quickly, supply more reliable and economical energy, and enable customers to have more control over their energy use (Bellman et al., 1970). Big data analytics can provide effective and efficient decision support for all of the producers, operators, customers and regulators in smart grid.

(Ben et al., 2007) discusses four major aspects of smart energy management, namely power generation side management, micro grid and renewable energy management, asset management and collaborative operation, as well as demand side management (DSM). A process model of big data driven smart energy management is proposed. Various techniques are also defined e.g. for Power generation side management- Constraint programming, fuzzy probabilistic model, Constraint programming and compromised modelling, Portfolio-theory, dynamic programming etc. for Micro grid and renewable energy management- Time series models, autoregressive(AR)models, artificial neural network

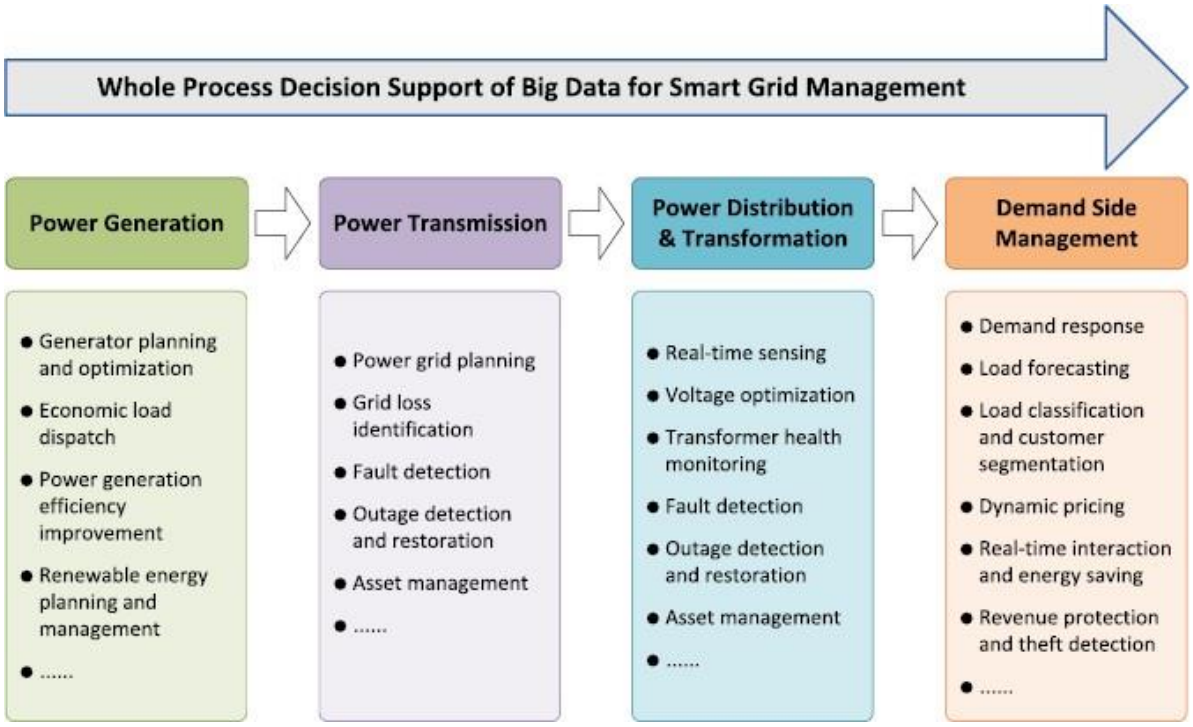

Fig. 2. Whole process decision support of big data for smart grid management

Focusses on embedding big data along with Internet of Things. Integration of big data, IoT along web via a smart gateway provides a universal communication platform to overcome the platform incompatibilities of smart things. Big Data analytics to enhance data processing speed. Authentic data sets are evaluated to determine the threshold values for intelligent decision-making and to present the performance improvement gained in data processing. The whole architecture can be used for network performance and energy management of smart buildings.

Multi-agent control system has been developed in combination with stochastic intelligent

optimization. The multi-objective genetic algorithm (MOGA) and hybrid multi-objective genetic algorithm (HMOGA) are used as optimization algorithms. The corresponding case study simulations of effective management of energy and user comfort are presented. The developed control system provides substantial enhancement in energy efficiency and indoor environmental comfort in smart buildings. An energy efficiency of 31.6% has been achieved with an 8.1% improvement of comfort index using the HMOGA technique.

A multi agent controller structure to manage energy consumption and occupants comfort was developed. It employed particle swarm optimization (PSO) at the central agent to observe the trade-off solutions for informed decision-making. Consequently, indoor comfort index parameters (thermal, visual and air quality) that were handled in (Shaikh et al., 2013, 2014) using genetic algorithm for optimization of comfort parameters properly.

Energy management systems are designed to monitor, optimize, and control the smart grid energy market. Demand-side management, considered as an essential part of the energy management system, can enable utility market operators to make better management decisions for energy trading between consumers and the operator. In this system, a priori knowledge about the energy load pattern can help reshape the load and cut the energy demand curve, thus allowing a better management and distribution of the energy in smart grid energy systems. Designing a computationally intelligent load forecasting (ILF) system is often a primary goal of energy demand management. This study explores the state of the art of computationally intelligent (i.e., machine learning) methods that are applied in load forecasting in terms of their classification and evaluation for sustainable operation of the overall energy management system. More than 50 research papers related to the subject identified in existing literature are classified into two categories: namely the single and the hybrid computational intelligence (CI)-based load forecasting technique. The advantages and disadvantages of each individual techniques also discussed to encapsulate them into the perspective into the energy management research. The identified methods have been further investigated by a qualitative analysis based on the accuracy of the prediction, which confirms the dominance of hybrid forecasting methods, which are often applied as meta heuristic algorithms considering the different optimization techniques over single model approaches. Based on extensive surveys, the review paper predicts a continuous future expansion of such literature on different CI approaches and their optimizations with both heuristic and metaheuristic methods used for energy load forecasting and their potential utilization in real-time smart energy management grids to address future challenges in energy demand management

3. Scope of the work

In order to harness the benefits of Green Energy, Dayalbagh Educational Institute (D.E.I.) has taken initiatives in harnessing the renewable energy through Solar thermal and Solar Photovoltaic (SPV) power plants. The institute has Solar Thermal Cooking systems in all the hostels. The whole university campus is powered by 9 Distributed Roof-Top Solar PV power Plants aggregating to a total of 558.2 kWp. These solar power plants with battery backup serve the following multiple objectives:

(i) providing uninterrupted power to the institute without using Diesel during power interruptions and minimizing environmental and noise pollution in the campus

(ii) the institute is self-sufficient in energy and is practically off-grid during the working hours of the institute

Therefore, while actively participating, and contributing in the National Solar Mission, the Institute is also helping in the much-needed man-power development which is essential for sustaining the Mission.

A smart micro-grid has been developed indigenously in the institute with centralized monitoring of all the power plants and the data is available on sql server in Microsoft Azure cloud. Therefore, required platform is now available for Data analytics and Machine learning applications to further improve and optimize the operations in the micro grid.

In the proposed work, focus will be on the following topics:

1. Smart Monitoring of solar panels, inverters, battery banks and loads through dashboard using R, with warnings and fault condition reporting on mobile phones of the operator and supervisor
2. Using machine learning to predict solar power output
3. Machine learning techniques to increase accuracy of solar forecasts in order to optimize energy production by solar power stations.

4. Grid Optimization- Uncertainty in renewable energy forecasting and load demand, increase the utility of the battery and solar power in order to achieve the long term objective of reducing the power consumption from grid.
5. Demand Forecasting-Forecast demand of various products using time series data of 2 years
6. A Fuzzy Goal Programming Model to fulfil our objective of high economy and high reliability. To design real-time power management strategies for MGs using intelligent control, considering maximum feasible energy sustainability, reliability and efficiency while, minimizing cost and undesired environmental impact (emissions).
7. Intelligent load control - demand response (DR)

References:

Aalami H, Moghaddam M P, Yousefi G, "Modeling and prioritizing demand response programs in power markets". Electr Power Syst Res 2010; 80:426–35

Altın M, Goksu O, Teodorescu R, Rodriguez P, Jensen B- B, Helle L. Overview of recent grid codes for wind power integration. In: Proceedings of the 2010 12th international conference on optimization of electrical and electronic equipment (OPTIM). IEEE; 2010. p.1152–60.

Amin M., "Challenges in reliability, security, efficiency, and resilience of energy infrastructure: Toward smart self-healing electric power grid". In: Proceedings of the power and energy society general meeting-conversion and delivery of electrical energy in, 2008 IEEE.IEEE; 2008.p.1– 5.

Aouni, B., Colapinto, C., La Torre D. (2013). A cardinality constrained stochastic goal programming model with satisfaction functions for venture capital investment decision making. Annals of Operations Research, 205 (1), 77-88.

Aouni, B., Colapinto, C., La Torre D. (2014). Portfolio Management through Goal Programming: State-of-the-art. European Journal of Operations Research, 234, 536-545.

Arnette A., Zobel C. W. (2012), An optimization model for regional renewable energy Development Review Article, Renewable and Sustainable Energy Reviews, 16(7), 4606-4615.

Bellman, R.E., Zadeh, L.A. (1970). Decision making in a fuzzy environment. Management Sciences, 17, B141-B164.

Ben Abdelaziz, F., Aouni, B., El Fayedh, R. (2007). Multi-objective stochastic programming for portfolio selection. European Journal of Operational Research, 177, 1811–1823.

Bhattacharya A, Chattopadhyay PK. Bio geography-based optimization for different economic load dispatch problems. IEEE Trans Power Syst 2010; 25:1064–77

Chen Y, Luh P B, Guan C, Zhao Y, Michel LD, Coolbeth MA, et al. Short-term load forecasting similar day-based wavelet neural networks. IEEE Trans Power Syst 2010; 25:322–30.

Deepak Kumar Lal, Bibhuti Bhusan Dash, and A. K. Akella,Optimization of PV/Wind/Micro-Hydro /Diesel Hybrid Power System in HOMER for the Study Area International Journal on Electrical Engineering and Informatics - Volume 3, Number 3, 2011.

Diagne, M., David, M., Lauret, P., Boland, J., Schmutz, N.: Review of solar irradiance forecasting methods and a proposition for small-scale insular grids. Renewable and Sustainable Energy Reviews 27 (2013) 65-76

Fan S, Hyndman R J. Short-term load fore casting based on a semi-parametric additive model. IEEETransPowerSyst2012; 27: 134–41.

Ferreira A, Cavalcante CA, Fontes CH, Marambio JE. A new method for pattern recognition in load profiles to support decision-making in the management of the electric sector .IntJElectrPowerEnergySyst2013;53:824–31

Francesco Grimaccia, Marco Mussetta, Riccardo Zich, "Neuro-fuzzy predictive Model for PV energy production based on weather forecast" 2011 IEEE International Conference on Fuzzy Systems (FUZZ-IEEE 2011)

Grandjean A, Adnot J, Binet G. A review and an analysis of the residential electric load curve models. Renew Sustain EnergyRev2012;16:6539–65.

Hugo T.C.Pedro. F.M.Coimbra, "Assessment of forecasting techniques for solar power production with no exogenous inputs". Elsevier Solar Energy 86 (2012) 2017–2028

Hugo T.C.Pedro, EdwinLim, Carlos F.M.Coimbra, "A database infrastructure to implement real-time solar and wind power generation intra-hour forecasts". ELSEVIER Renewable Energy Volume 123, August 2018, Pages 513-525

Hong WC. Electric load forecasting by seasonal recurrent SVR (support vector regression) with chaotic artificial bee colony algorithm. Energy 2011; 36:5568–78.

Hossain, M.R., Amanullah, M.T.O., Shawkat Ali, A.B.M.: Hybrid prediction method of solar power using different computational intelligence algorithms. In: Proceedings of the 22nd Australasian Universities Power Engineering Conference (AUPEC). (2012) 1-6

M. Ricardo Saavedra M., Cristiano Horade O. Fontes, Francisco GaudêncioM. Freires, "Sustainable and renewable energy supply chain: A system dynamics overview". ELSEVIER Volume 82, Part 1, February 2018, Pages 247-259.

Juan Manuel Carrasco, Jan T. Bialasiewicz, Ramón C. Portillo Guisado, "Power-Electronic Systems for the Grid Integration of Renewable Energy Sources. IEEE TRANSACTIONS ON INDUSTRIAL ELECTRONICS, VOL. 53, NO. 4, AUGUST 2006

Kazemi, A., Mehregan, M. R., & Shakouri, H. (2011). Energy supply model for Iran with an emphasis on greenhouse gas reduction. In Proceedings of the 41st international conference on computers & industrial engineering (pp. 491–496)

Kalogirou, S.A., Panteliou, S., Dentsoras, A: Artificial neural networks used for the performance prediction of a thermosiphon solar water heater. Renewable Energy 18 (1999) 87-99

Khalil Benmouiza, Ali Cheknane, "Forecasting hourly global solar radiation using hybrid *k*-means and nonlinear autoregressive neural network models". Elsevier, Energy Conversion and Management, 75(2013) 561-569

Kiker, G.A., et al. (2005) Application of Multi-criteria Decision Analysis in Environmental Decision Making. Integrated Environmental Assessment and Management, 1, 95-108

Leo Rajua, Sibi Sankara, Milton R Sa, “Distributed Optimization of Solar Micro-grid using Multi Agent Reinforcement Learning’ International Conference on Information and Communication Technologies (ICICT 2014)

Momoh J.A, “Smart grid design for efficient and flexible power networks operation and control. In: Proceedings of the power systems conference and exposition, 2009 PSCE'09IEEE /PES.IEEE; 2009.p.1–8.

Nehrir M.H, and Sastry C, “Providing Ancillary Services through Demand Response with Minimum Load Manipulation,” in *Proceedings*, 2011 North American Power Symposium, August 4-6, Boston, MA.

Phiri S.K and Kusakana, K,. Demand Side Management of a grid connected PV-WT-Battery hybrid system. IEEE, OCT 2016

Pourmousavi .S.A and Nehrir M.H, “Demand Response for Smart Microgrid: Initial Results, in Proceedings, 2011 IEEE Innovative Smart Grid Technologies Conference, Jan. 16-19, Anaheim CA

Pourmousavi .S.A and Nehrir M.H, “Real-Time Central Demand Response for Primary Frequency Regulation in Microgrids,” *IEEE Transactions on Smart Grid (Special issue on Microgrid)*, Vol. 3, No. 4, December 2012. Also presented at the 2013 IEEE PES General Meeting, July 21-25, Vancouver, B.C., Canada

Pourmousavi S.A, Nehrir M.H, “Real-Time Optimal Demand Response for Frequency Regulation in Smart μGrid,” in *Proceedings*, 2012 IASTED Power and Energy Systems Conference (Euro PES 20112), June 25-27, Naples, Italy.

Sharma, N., Sharma, P., Irwin, D., Shenoy, P.: Predicting solar generation from weather forecasts using machine learning. In: Proceedings of the 2011 IEEE International Conference on Smart Grid Communications (SmartGridComm). (2011) 528-533

Samadi P, Mohsenian-RadA-H, SchoberR, WongVW, JatskevichJ. Optimal real-time pricing algorithm based on u tility maximization for smart grid. In: Proceedings of the 2010 first IEEE international conference on smart grid communications (SmartGridComm). IEEE; 2010.p. 415–20.

Seyedeh Narjes Fallah, Ravinesh Chand Deo, Mohammad Shojafar, Mauro Conti and Shahaboddin Shamshirband, “Computational Intelligence Approaches for Energy Load Forecasting in Smart Energy Management Grids: State of the Art, Future Challenges, and Research Directions”. MDPI Mar, 2018.

Shaikh PH, Nor NBM, Nallagownden P, Elamvazuthi I, Ibrahim T. Robust stochastic control model for energy and comfort management of buildings. Aust J Basic Appl Sci 2013; 7(10):137–44.

Shaikh PH, Nor NBM, Nallagownden P, Elamvazuthi I. Building energy management through a distributed fuzzy inference system. Int J Eng Technol 2013; 4:3236–42.

Shaikh PH, Nor N Mohd, Nallagownden P, Elamvazuthi I. Stochastic optimized intelligent controller for smart energy efficient buildings. Sustain Cities Soc 2014; 13:41–5.

Sheeraz Kirman, Majid Jamil, Iram Akhtar, "Development of Effective Technique for Integration of Hybrid Energy System to Microgrid", Proceedings of First International Conference on Smart System, Innovations and Computing pp 51-61, Jan 2018

Wang Z, Yang R, Wang L. Intelligent multi-agent control for integrated building and micro-grid system. In: IEEE PES innovative smart grid technologies. Anaheim (CA); 2011. p.1–7.

Weicong Kong; Zhao Yang Dong; Youwei; David J.Hill; Yan Xu; Yuan Zhang, "Short-Term Residential Load Forecasting based on LSTM Recurrent Neural Network". IEEE Transactions on Smart Grid (Volume: PP, Issue: 99), Sep 2017

Zhou K, Yang S,ChenZ, Ding S .Optimal load distribution model of micro grid in the smart grid environment. RenewSustainEnergyRev2014; 35:304–10.

Zhou K, YangS, ShenC. A review of electric load classification in smart grid environment. Renew Sustain Energy Rev 2013; 24:103–10.

Zhou K, Fu C, Yang S. Fuzziness parameter selection in fuzzy c-means: The perspective of cluster validation.SciChinaInfSci2014;57:1–8.

Zhou K, Ding S, FuC, YangS. Comparison and weighted summation type of fuzzy cluster validity indices.IntJComputCommunControl2014;9:370–8.

Zho u K, YangS, ShenC, DingS, SunC. Energy conservation and emission reduction of China's electric power industry. Renew Sustain Energy Rev 2015;45:10–9.